REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE Technical Papers	3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE

Please see attached

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
2302
5e. TASK NUMBER
M1G2
5f. WORK UNIT NUMBER
346120

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)
AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

8. PERFORMING ORGANIZATION REPORT

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Air Force Research Laboratory (AFMC)
AFRL/PRS
5 Pollux Drive
Edwards AFB CA 93524-7048

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S NUMBER(S)

Please see attached

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

20030129 107

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Leilani Richardson
a. REPORT	b. ABSTRACT	c. THIS PAGE	A		19b. TELEPHONE NUMBER (include area code) (661) 275-5015
Unclassified	Unclassified	Unclassified			

MEMORANDUM FOR PR (Contractor/In-House Publication)

FROM: PROI (TI) (STINFO)   16 Jun 2000

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-2000-132**
C.W. Smith, K.T. Gloss, D.M. Constantinescu (Virginia Polytechnic Institute & State University); C.T. Liu (AFRL/PRSM), "Stress Intensity Factors for Cracks Within and Near to Bondlines in Soft Incompressible Materials"

ASME International Mechanical Engineering Conference   **(Statement A)**
(Orlando, FL, 5-10 Nov 2000)   **(Submission Deadline: 20 July 2000)**

1. This request has been reviewed by the Foreign Disclosure Office for: a.) appropriateness of distribution statement,
b.) military/national critical technology, c.) export controls or distribution restrictions,
d.) appropriateness for release to a foreign nation, and e.) technical sensitivity and/or economic sensitivity.
Comments:_____
_____
_____
_____

Signature _____   Date _____

2. This request has been reviewed by the Public Affairs Office for: a.) appropriateness for public release
and/or b) possible higher headquarters review.
Comments: _____
_____
_____
_____

Signature _____   Date _____

3. This request has been reviewed by the STINFO for: a.) changes if approved as amended,
b.) appropriateness of distribution statement, c.) military/national critical technology, d.) economic sensitivity,
e.) parallel review completed if required, and f.) format and completion of meeting clearance form if required
Comments:_____
_____
_____

Signature _____   Date _____

4. This request has been reviewed by PR for: a.) technical accuracy, b.) appropriateness for audience, c.)
appropriateness of distribution statement, d.) technical sensitivity and economic sensitivity, e.) military/
national critical technology, and f.) data rights and patentability
Comments:_____
_____

APPROVED/APPROVED AS AMENDED/DISAPPROVED

_____
LESLIE. S. PERKINS, Ph.D   (Date)
Staff Scientist
Propulsion Directorate

STRESS INTENSITY FACTORS FOR CRACKS WITHIN AND NEAR TO BONDLINES IN SOFT INCOMPRESSIBLE MATERIALS

C. W. SMITH[†], K. T. GLOSS[†],
D. M. CONSTANTINESCU[†] AND C. T. LIU[‡]

[†] Department of Engineering Science and Mechanics,
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

[‡] Air Force Research Laboratory PRSM
10 E. Saturn Blvd.
Edwards AFB, CA 93524-7680

2

ABSTRACT

Using a polyurethane photoelastic material, thick test specimens of several configurations with bonded end tabs are examined for measuring stress intensity factors (SIFs) for cracks within and near to bondlines in bonded photoelastic models. Effects of specimen height, glued end tabs, bondline and crack size and location are studied and analyzed using a two parameter model for extracting the SIFs and results are compared with cracked, homogeneous model results.
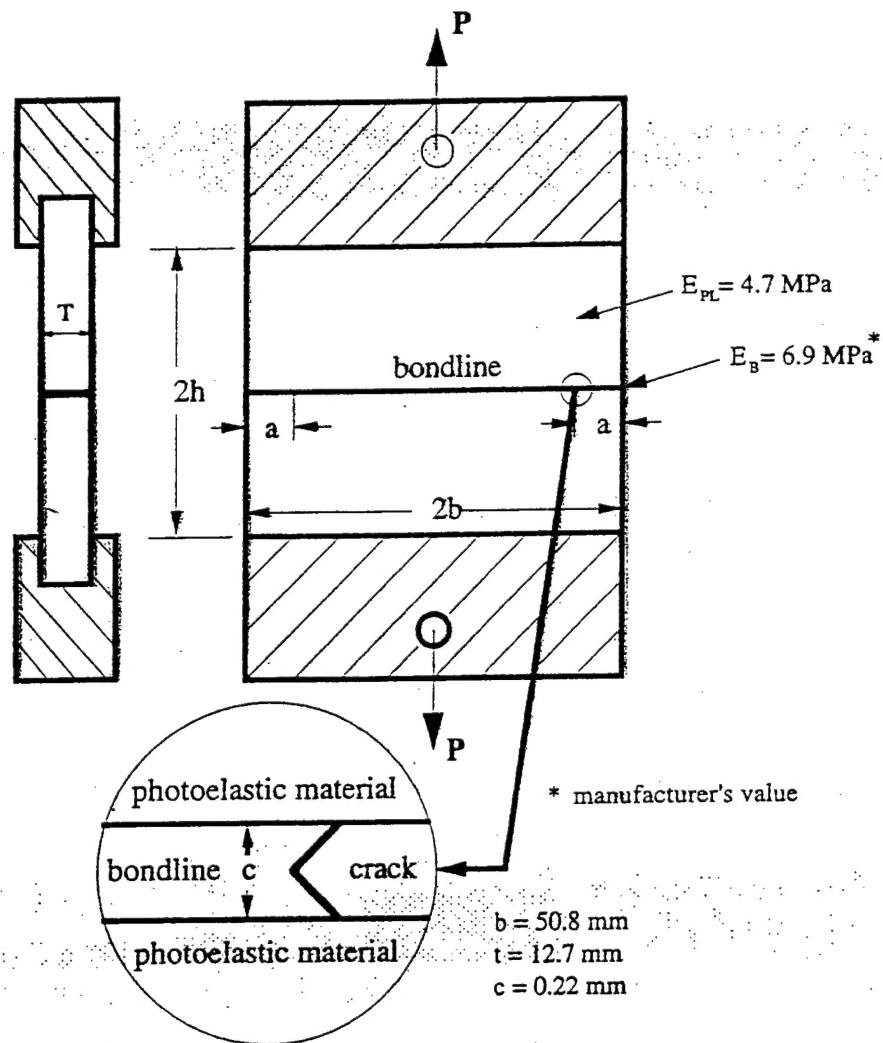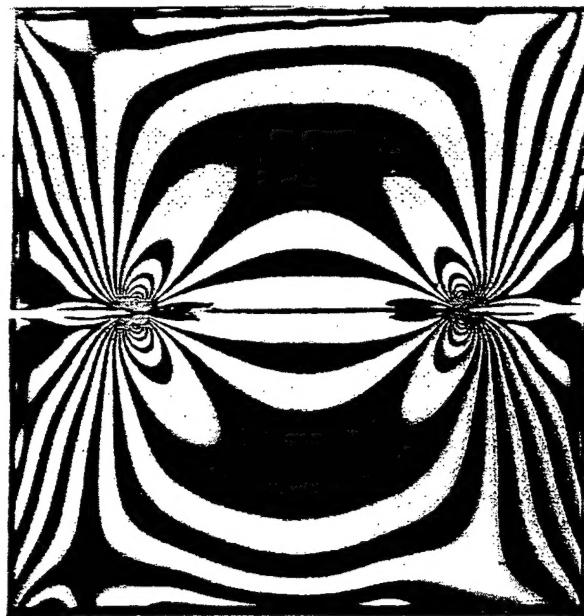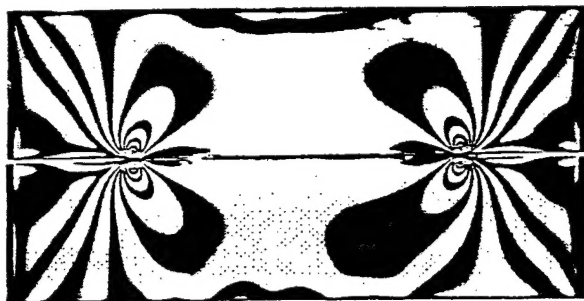
P

E_{PL} = 4.7 MPa

E_B = 6.9 MPa*

bondline

T

2h

a

a

2b

P

photoelastic material

bondline   c

crack

photoelastic material

* manufacturer's value

b = 50.8 mm
t = 12.7 mm
c = 0.22 mm

Figure 1   Test Setup for Bonded Specimens Containing Double Edge Bondline Cracks.

4

a)

| 20.6 mm |

b)

Figure 2   Global Stress Fringe Patterns for Bondline Cracks in a) Square and b) Half Height Specimens. Note effects of imperfections in glued joints on top and bottom and slight dissymmetry in local fringe patterns (Integral Fringes White).

[handwritten annotation] Is this saying the white sections are integral fringes? If so, please make more clear.

data zone

bondline

data zone

1.32 mm

a)

data zone
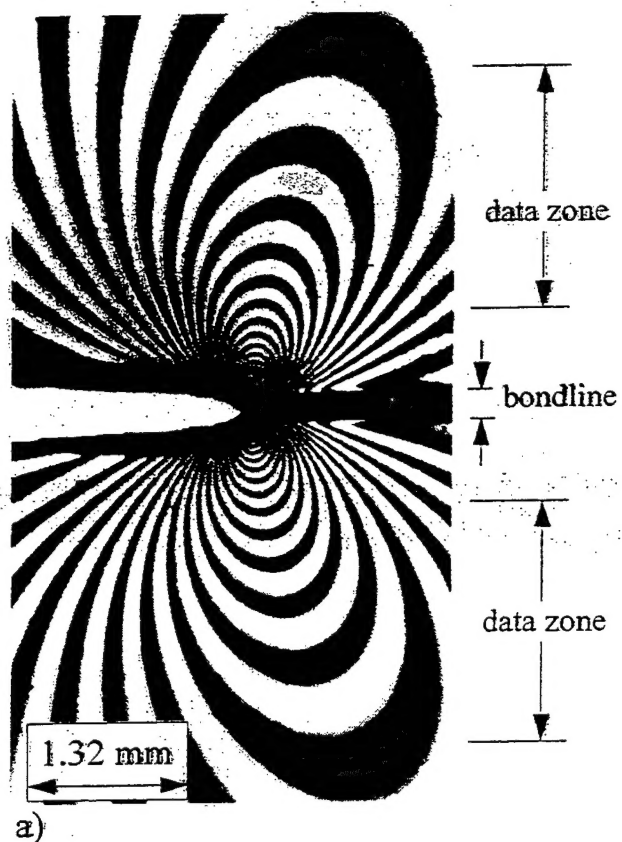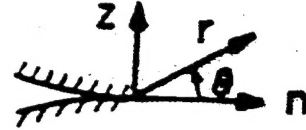
bondline

data zone

1.22 mm

b)
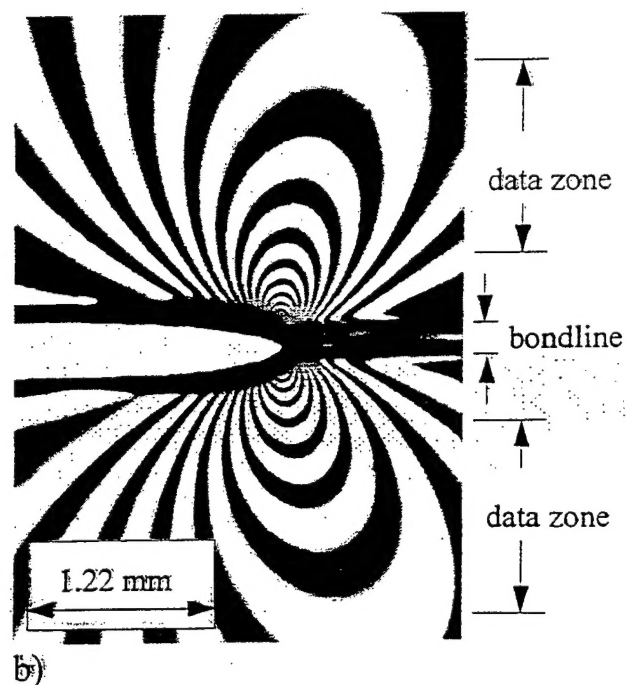
Figure 3 Local Stress Fringe Patterns for Bondline Cracks in both a) Square and b) Half Height Specimens. Absence of rotation of fringe patterns confirms pure Mode I loading (Integral Fringes White).

3

Mode I Algorithm for Homogeneous Case for Converting Optical Data into Stress Intensity Factor (SIF) Values.

Beginning with the Giffith-Irwin Equations, we may write, for Mode I, for the homogeneous case

$$\sigma_{ij} = \frac{K_1}{(2\pi r)^{1/2}} \, t_{ij}(\theta) + \sigma_{ij}^* \quad (i, j, = n, z) \quad (1)$$

where: σ_{ij} are components of stress, K_1 is SIF, r, θ are measured from crack tip (Fig. A-1), σ_{ij}^* are non-singular stress components.

Then, along $\theta = \pi/2$, after truncating σ_{ij}

$$(\tau_{nz})_{max} = \frac{K_1}{(8\pi r)^{1/2}} + \tau^* = \frac{K_{AP}}{(8\pi r)^{1/2}} \quad (2)$$

where $\tau^* = f(\sigma_{ij}^*)$ and is constant over the data range, K_{AP} = apparent SIF, $(\tau_{nz})_{max}$ = maximum shear stress in nz plane

$$\therefore \frac{K_{AP}}{\sigma(\pi a)^{1/2}} = \frac{K_1}{\sigma(\pi a)^{1/2}} + \frac{\sqrt{8}\tau^*}{\sigma}\left(\frac{r}{a}\right)^{1/2} \quad (3)$$

where (Fig. A-1) a = crack length, and $\bar{\sigma}$ = remote normal stress i.e.

$$\frac{K_{AP}}{\sigma(\pi a)^{1/2}} \text{ vs. } \sqrt{\frac{r}{a}} \text{ is linear.}$$

Since from the Stress-Optic Law $(\tau_{nz})_{max} = nf/2t$ where, n = stress fringe order, f = material fringe value, t = specimen thickness, then from Eq. 2,

$$K_{AP} = (8\pi r)^{1/2} (\tau_{nz})_{max} = (8\pi r)^{1/2} \, nf/2t$$

A typical plot of normalized K_{AP} vs. $\sqrt{r/a}$ for a homogeneous specimen is shown in Fig. A-2.
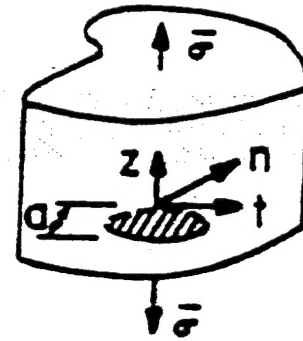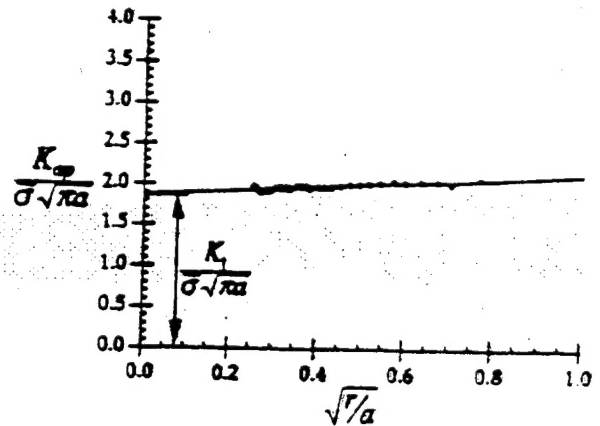
Figure A-1: Mode I Near-Tip Notation

Figure A-2 – Estimating Normalized SIF from Test Data

Table I - Data and Results for Cracks Within Bondline

test#	a(mm)	h(mm)	a/b	P (N)	exp K/Ko	exp. corr. ($\nu = 0.5$) K/Ko	Bowie[*] ($\nu = 0.3$) K/Ko
DS2	7.94	50.8	0.16	74.95	1.14	1.05	1.06
DS3	12.7	50.8	0.25	74.95	1.09	1.00	1.04
DS4	17.4	50.8	0.34	74.95	1.15	1.06	1.04
DS5	20.6	50.8	0.41	74.95	1.23	1.13	1.06
DS6	25.4	50.8	0.50	74.95	1.38	1.27	1.10
DS7	27.9	50.8	0.55	74.95	1.37	1.26	1.12
DS8	7.94	25.4	0.16	74.95	0.93	0.86	—
DS9	12.7	25.4	0.25	74.95	0.94	0.87	—
DS10	17.4	25.4	0.34	52.68	0.98	0.90	—
DS11	20.6	25.4	0.41	50.72	1.00	0.93	—
DS12	25.4	25.4	0.50	50.72	1.18	1.09	—
DS13	27.9	25.4	0.55	51.01	1.22	1.12	—

[*] plane stress, no bondline $K_0 = \bar{\sigma}\sqrt{\pi a}$

8

$P_1 + P_2 = 110.55$ N
$T = 12.70$ mm
$t = 0.23$ mm
$w = 101.6$ mm
$h = 50.8$ mm or 25.4 mm
$a =$ crack length
$d =$ offset distance
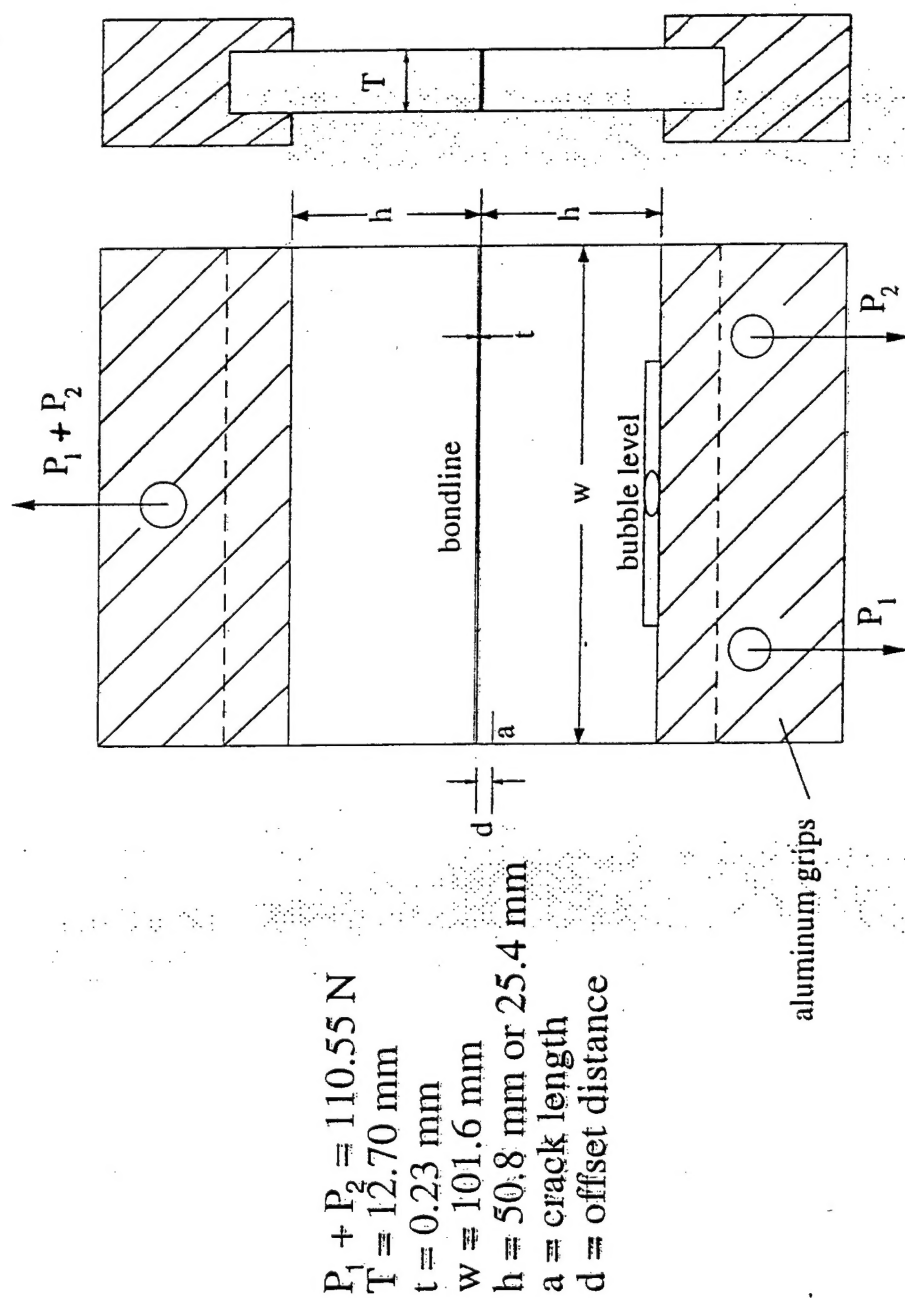
Figure 4 Test Setup for Bonded Specimens Containing Cracks Near to and Parallel to Bondline.

a)
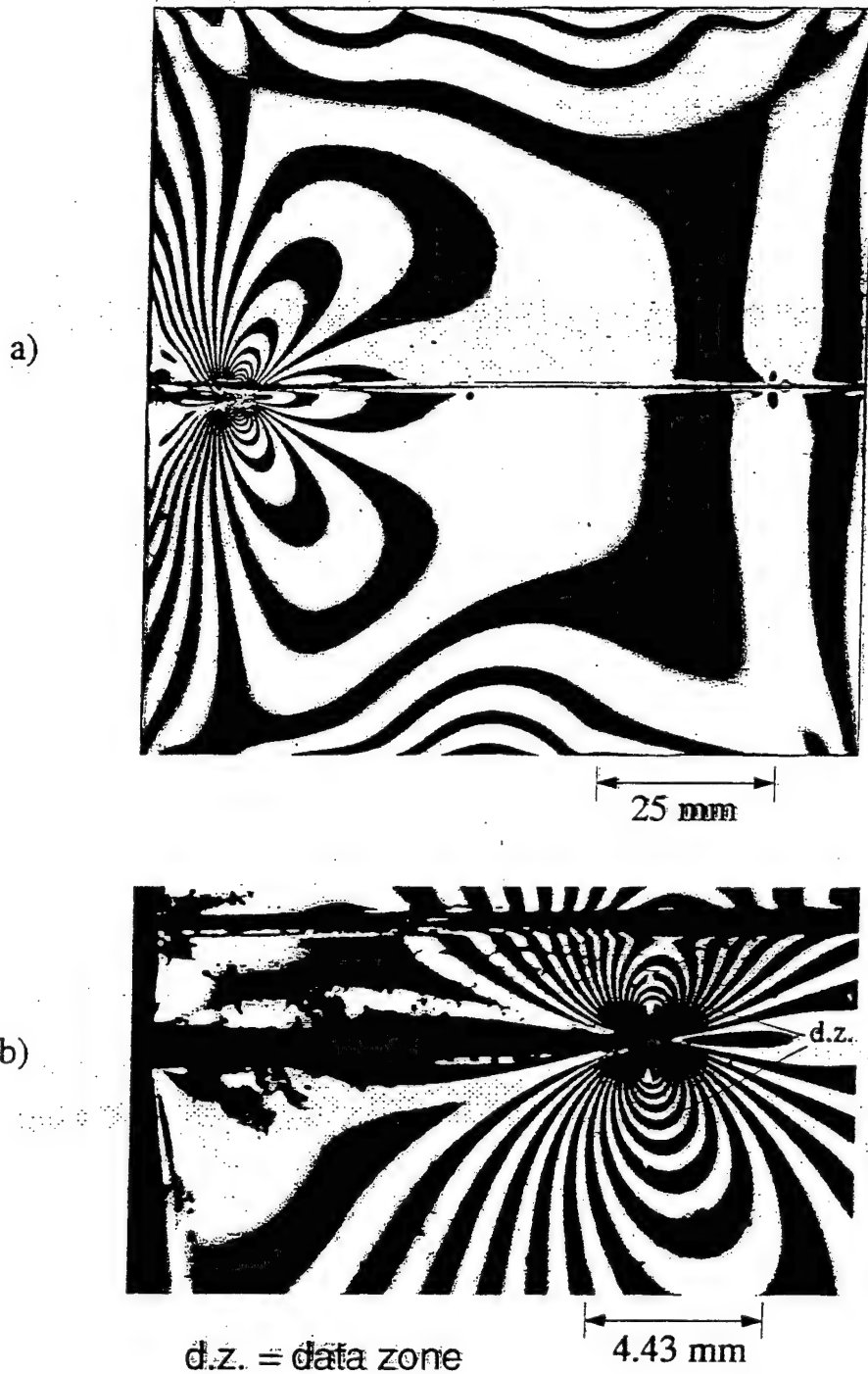
25 mm

b)

d.z.

4.43 mm

d.z. = data zone

Figure 5   a) Global and b) Local Stress fringe photos for a Square Specimen with Crack Parallel to Bondline. Note reduction in size of the linear zone above the crack. **Lack** of fringe loop rotation again confirms pure Mode I (Integral Fringes Dark).

make more clear (a.g. no capital letters)

Table 2 - Data and Results for Cracks Parallel to Bondline

$w = 101.6$

Test #	a	d	h	a/w	K^*/K_0
SP6	2.78	2.58	50.80	0.027	0.976
SP7	2.98	1.19	50.80	0.029	0.885
SP8	8.33	2.58	50.80	0.082	1.139
SP9	7.95	1.19	50.80	0.078	1.017
SP10	13.09	1.19	50.80	0.129	1.173
SP11	12.70	2.58	50.80	0.125	1.365
SP12	2.58	2.78	25.4	0.025	0.806
SP13	7.54	2.78	25.4	0.074	0.876
SP14	12.70	2.78	25.4	0.125	1.028

Dimensions in mm, * Corrected for 3-D effects to a 2D solution.

is this supposed to be Fig 6?
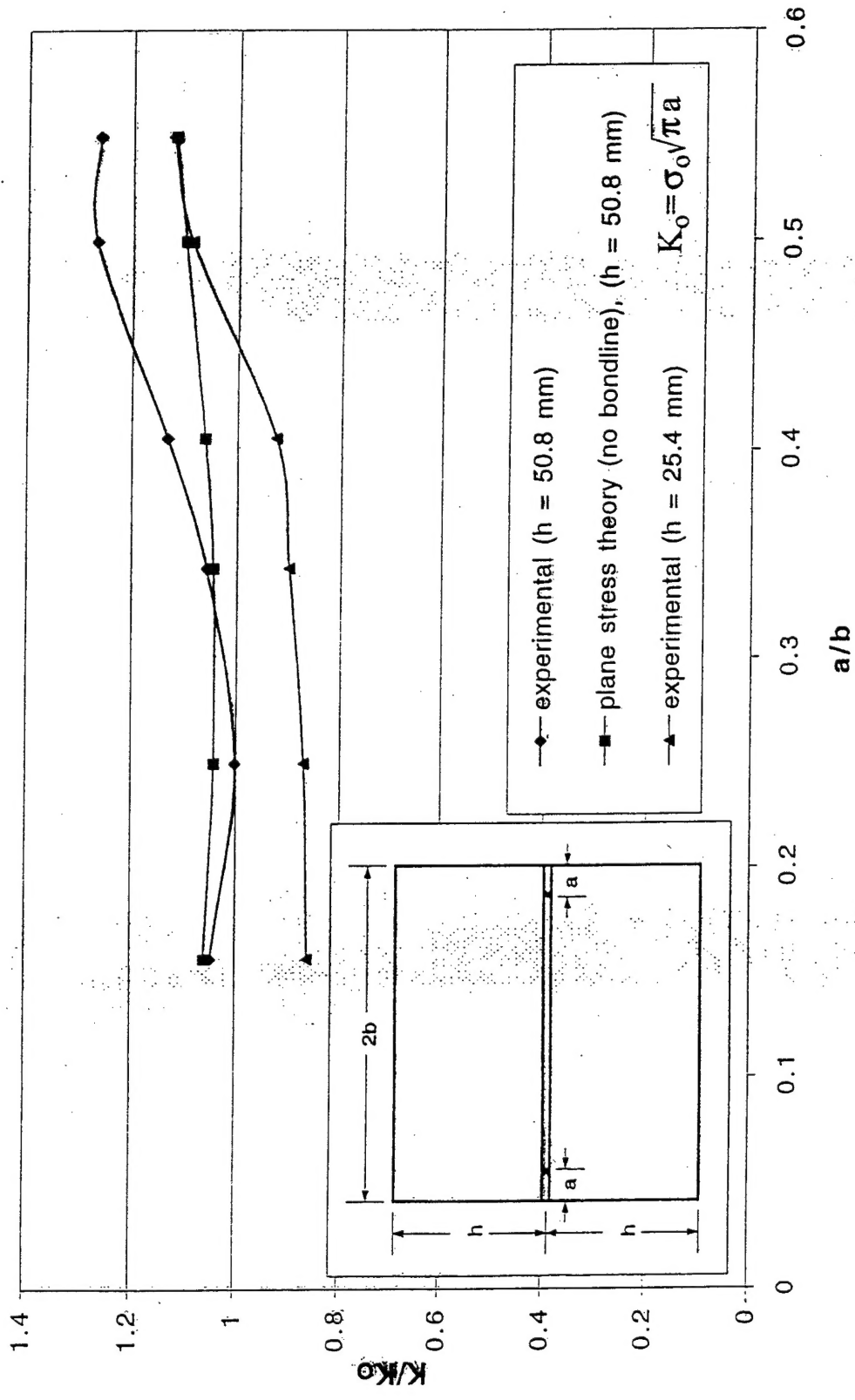If not, suggest removing figure and table titles because it leads the reader to believe something is missing.

Figure 7 Effect of Crack Length on Stress Intensity Factor (SIF). Note reduction in SIF due to reduced specimen height and elevation of SIF with increasing crack length in contrast to results from unbonded specimen.
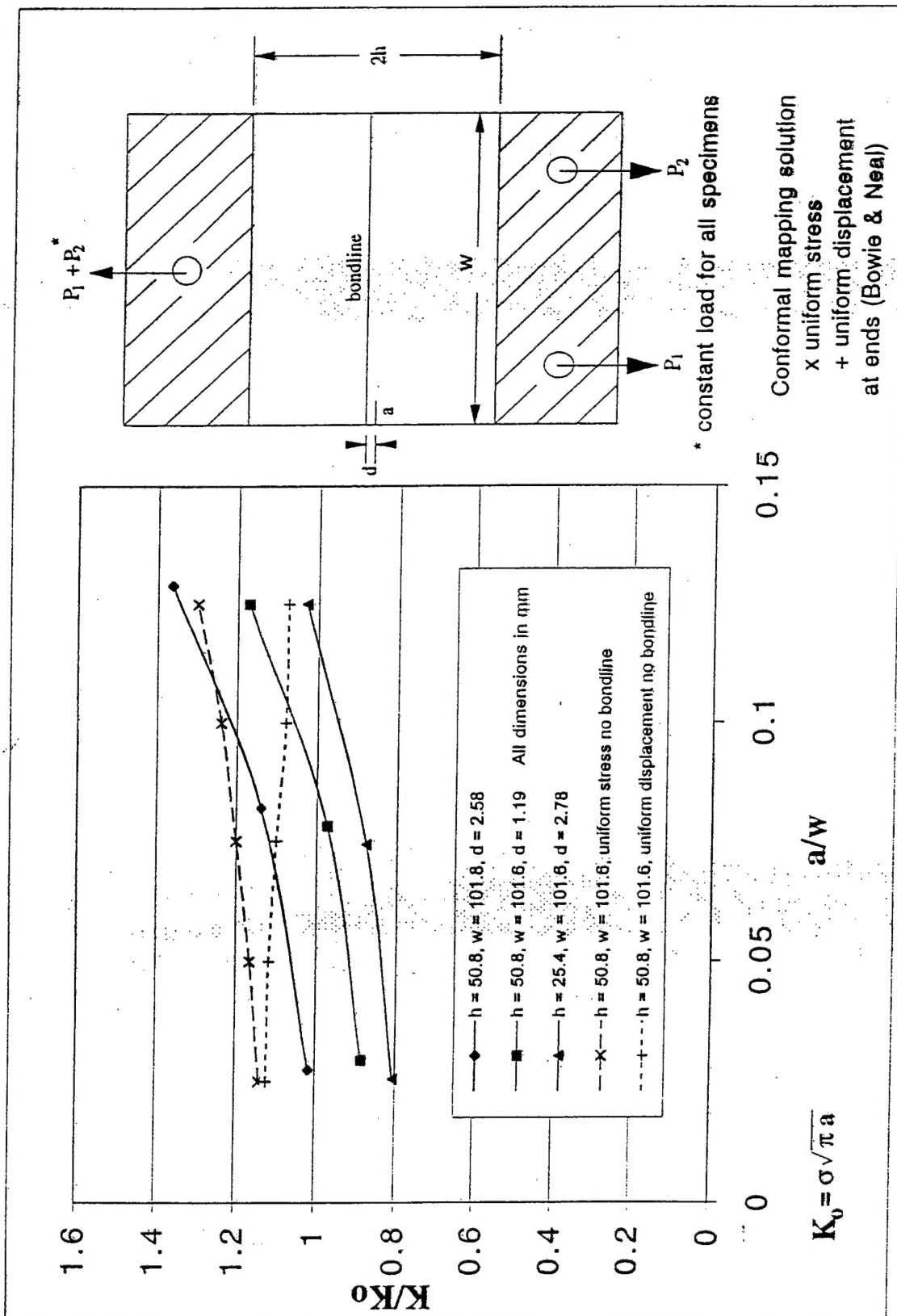
12

Figure 8 Effect of Crack Length and Specimen Height on SIF Compared with Analytical Results for Uniform Stress and Uniform Displacement in Homogeneous Models.

Summary

In summary, results show that:

1) Normalized SIFs increase with relative crack length for both square and half height bonded specimens more rapidly than indicated by solutions for unbonded specimens for both bondline cracks and cracks parallel to the bondline.

2) Reducing specimen height reduces normalized SIF's for all crack lengths in both bondline cracked specimens and those containing cracks parallel to the bondline. Since Torvik, (1979) indicated such an effect in unbonded edge cracked specimens, this reduction appears to be due to specimen shape rather than a bondline effect and may be conjectured to apply to the bondline cracked specimen results as well.

3) The experiments revealed

   a) No shear mode effect

   b) A shielding effect due to the bondline for short cracks and those with less separation from the bondline for the cracks parallel to the bondlines.

4) Imperfections in the glued tab arrangement were clearly shown.

ACKNOWLEDGMENTS